V Reunión de Ciencias Planetarias y Exploración del Sistema Solar

A LARGE-SCALE DISTURBANCE IN A SINGULAR TRIPLE VORTEX IN SATURN'S ATMOSPHERE

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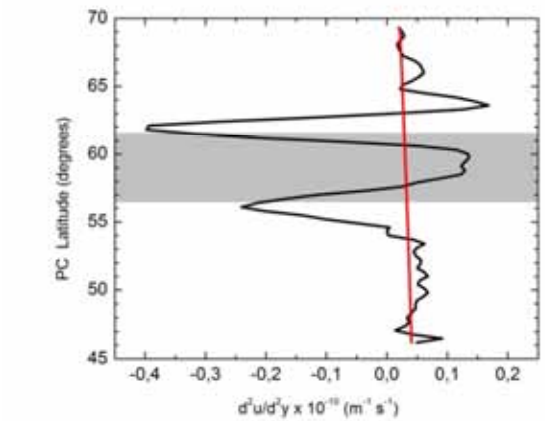
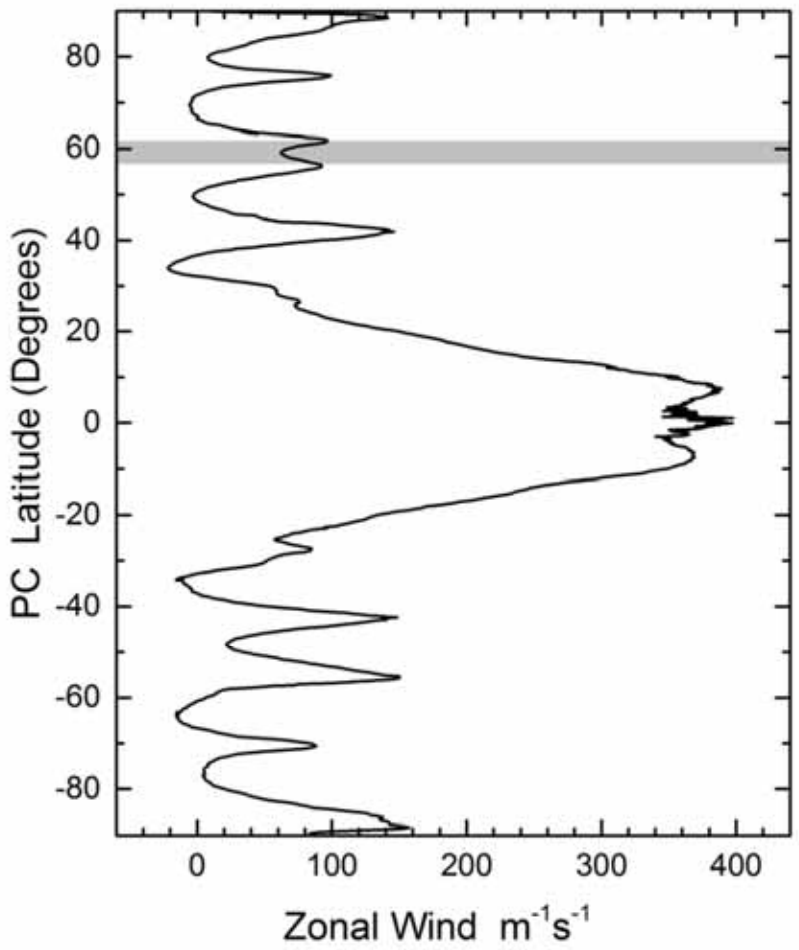
Motivation

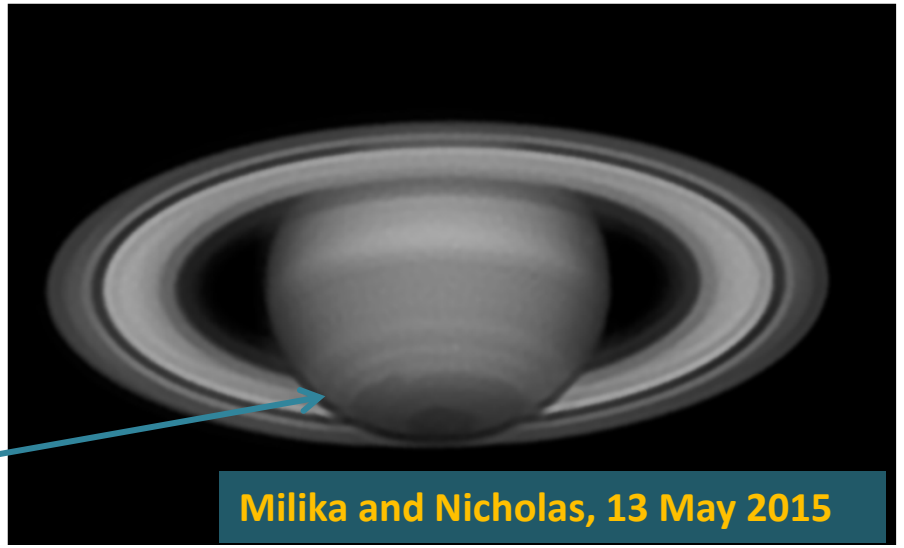
- ✓ The zonal wind profile of Saturn, like that of Jupiter, is approximately symmetric, with a strong prograde equatorial jet and four other eastward jets in the North and South.
- ✓ The jet at +60ºPC has a singular structure, with a double peak that is not present in any other jet either in Saturn or in Jupiter

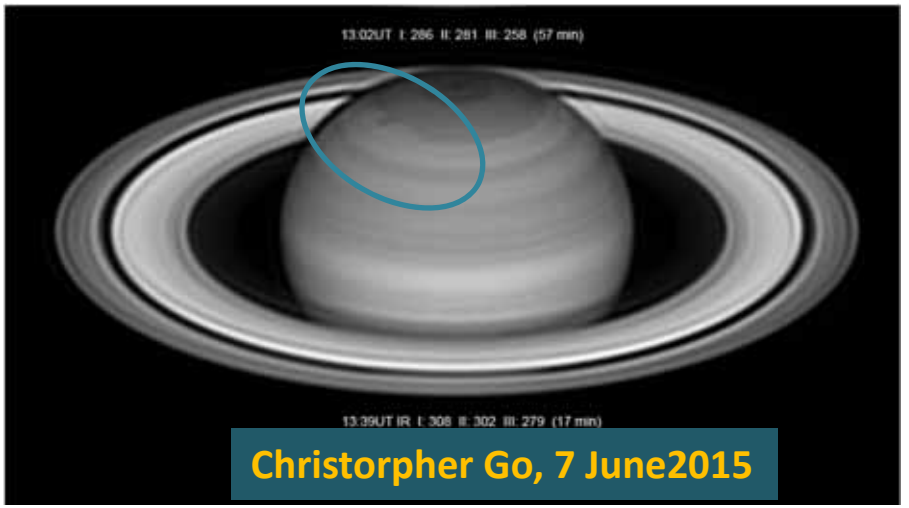




Motivation

- ✓ Amateurs were able to track the zonal motion of a “spot” in this region in 2014-2015
- ✓ At May 2015 the region surrounding the spot started changing
- ✓ A “rift” was reported, and later on a large and growing area appeared disturbed

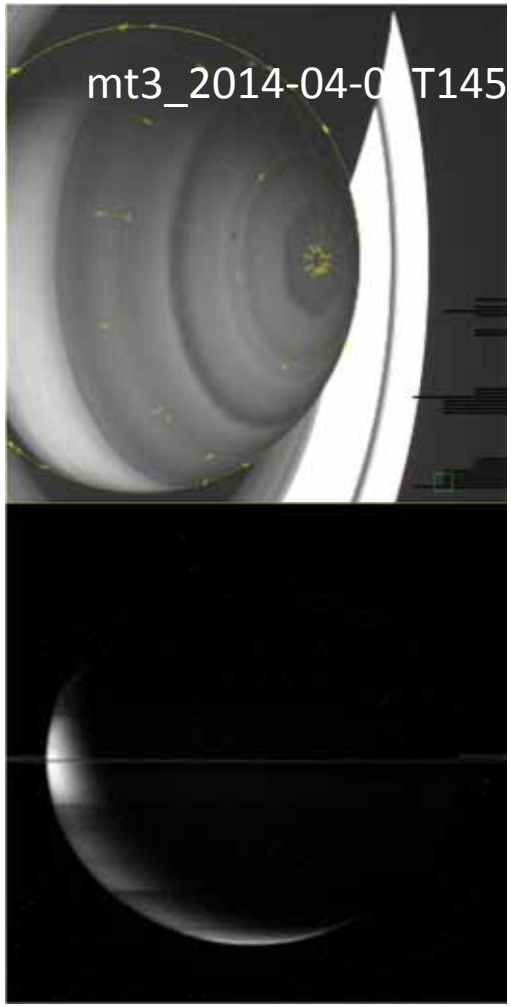




A look from Cassini

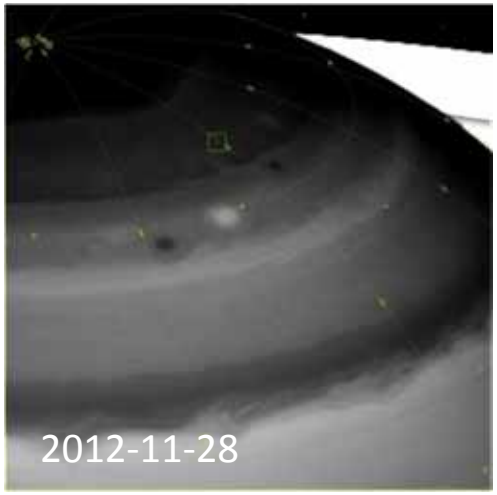
- ✓ A singular structure is the origin of the “spot” detected in amateur images
- ✓ Particularly easy to locate in MT3 filter, where it consists of a very compact dark spot surrounded by two bright areas at higher latitude.
- ✓ Cassini COISS archives were explored backwards in time to trace the origin of the system, showing that it has been present since 2012

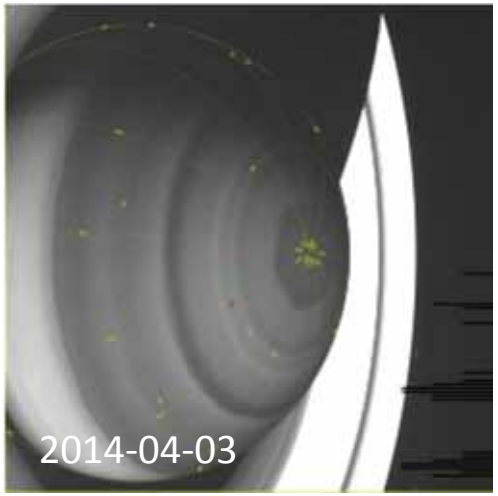
At the time of the disturbance, Cassini orbits were not favorable to the observation of the region : we were granted HST directory discretionary time



Organization of this talk

- ✓ The tripole system: History, evolution and local motions.

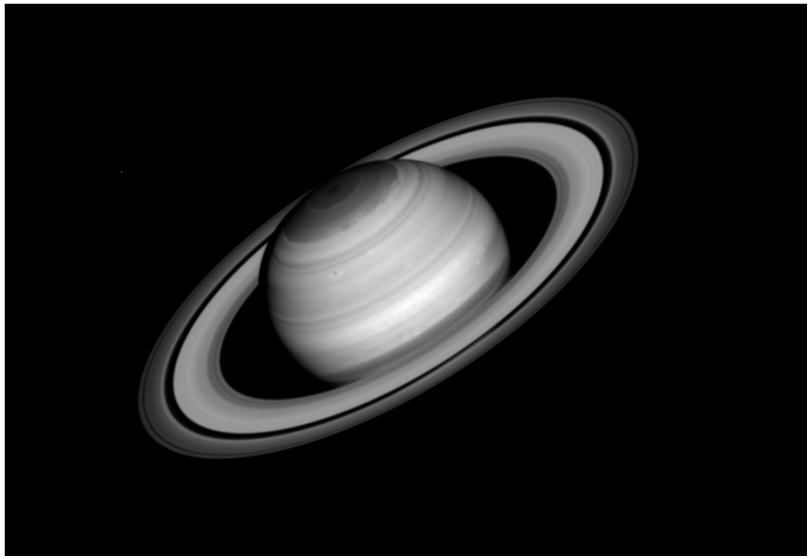




- ✓ The disturbance:

  Onset, evolution, possible origin.

- ✓ Numerical simulations



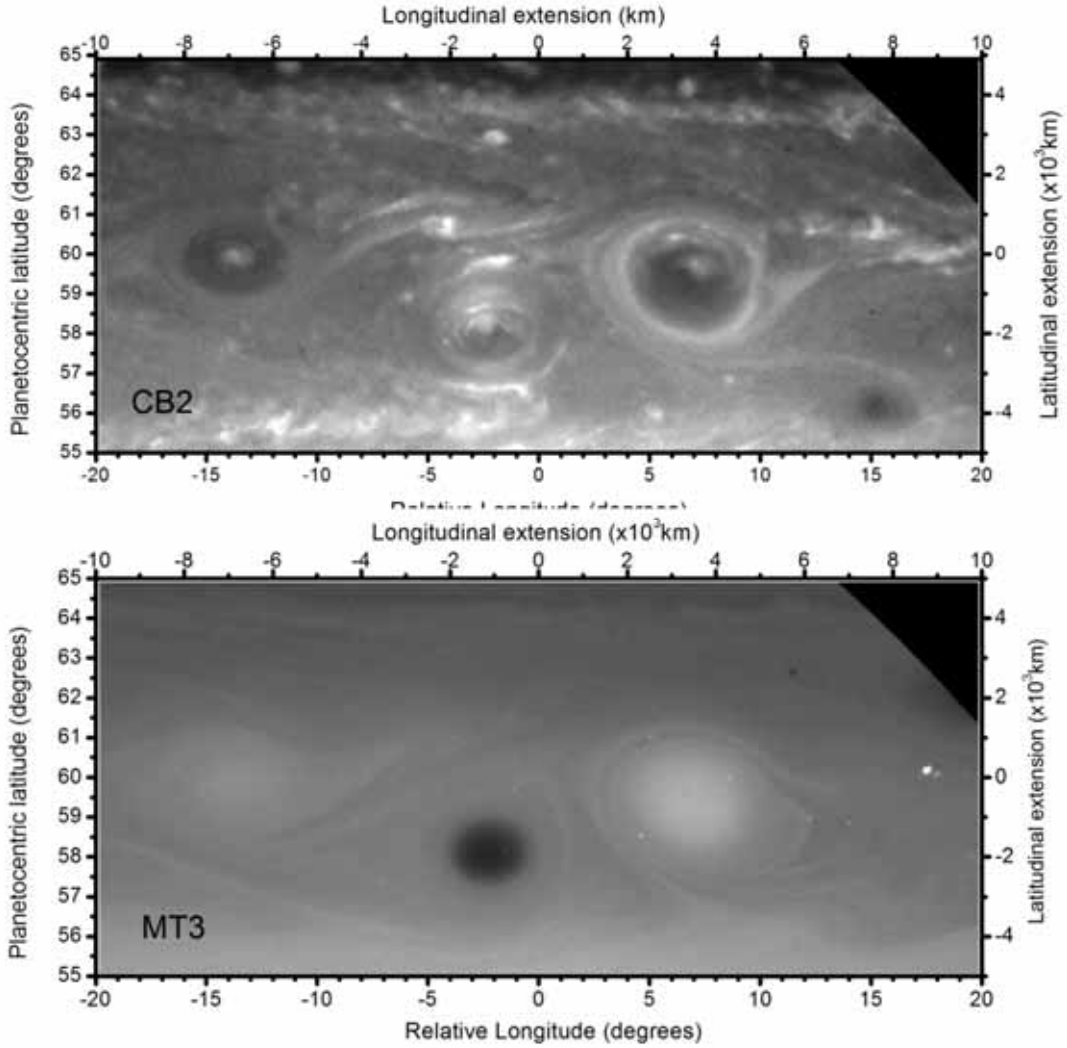
The tripole system

- ✓ CB2 and MT3 images suggest a cyclone surrounded by two anticyclones
- ✓ Relative longitudinal location of cyclone and anticyclones change in time
- ✓ Vortices are almost circular:

Cyclone (MT3)
1800 km x 2100 km

Anticyclones (CB2)
2600 km x 3300 km
1800 km x 2400km

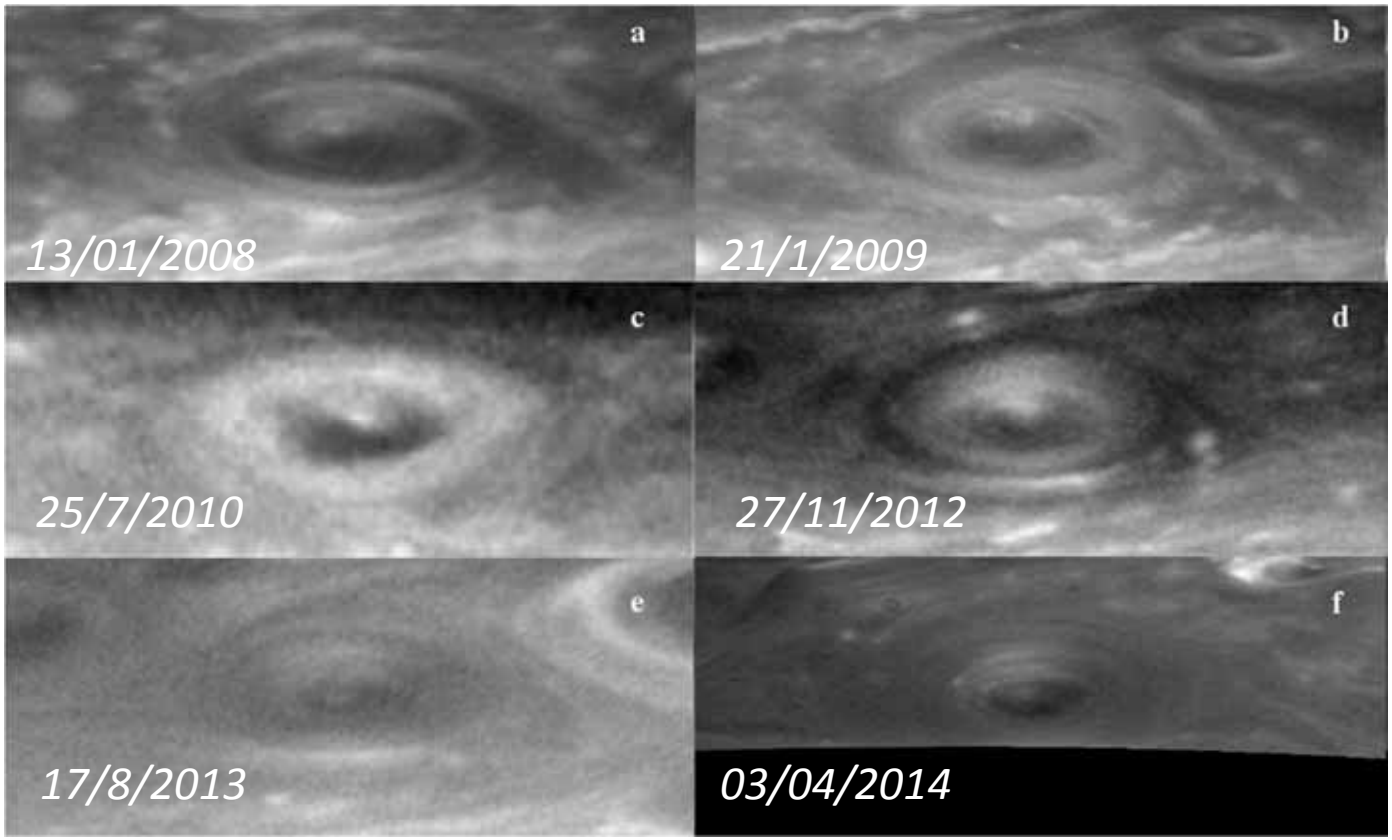
Errors of the order of 500km



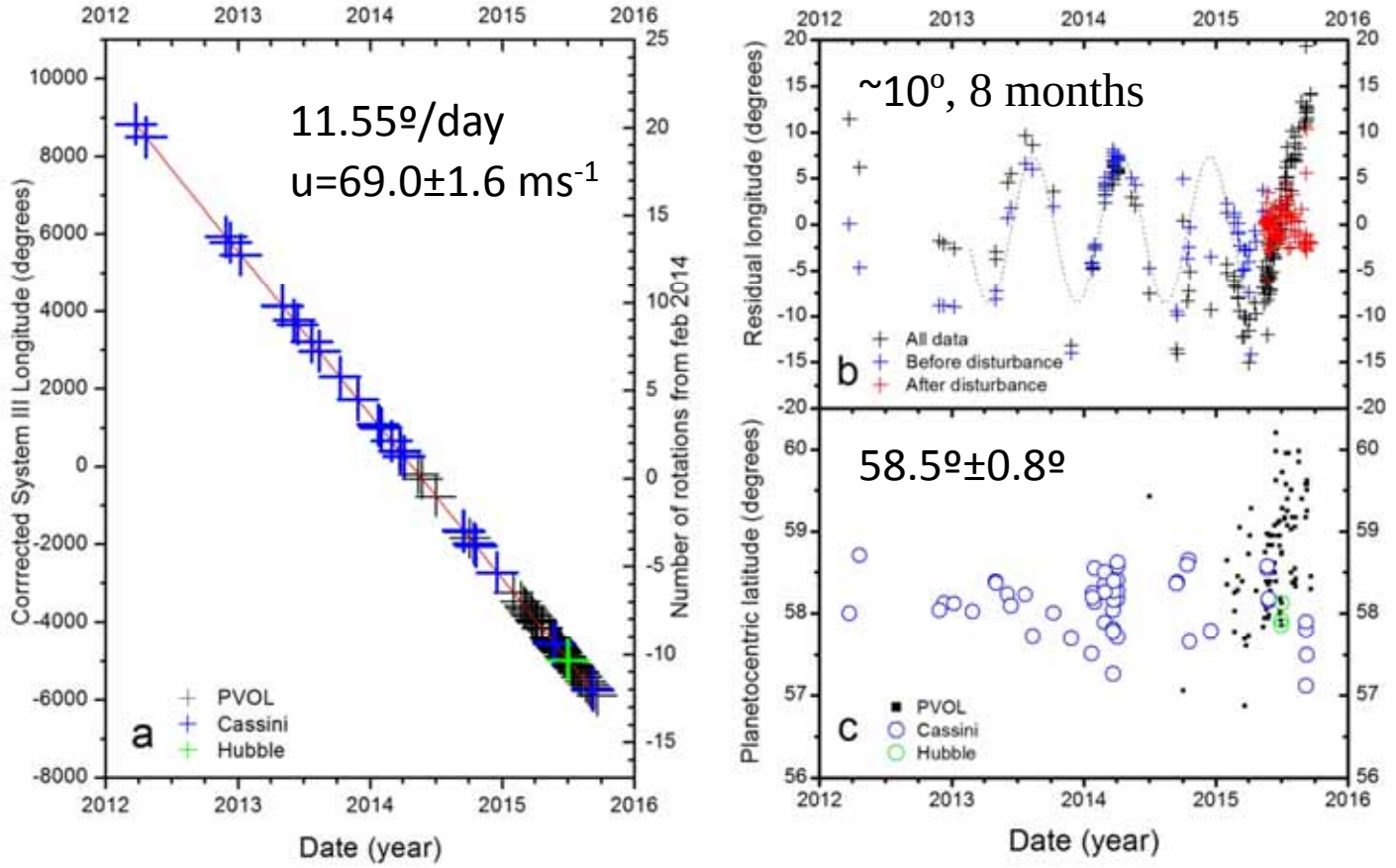
Images of 27th February 2013

A cyclone at the center.

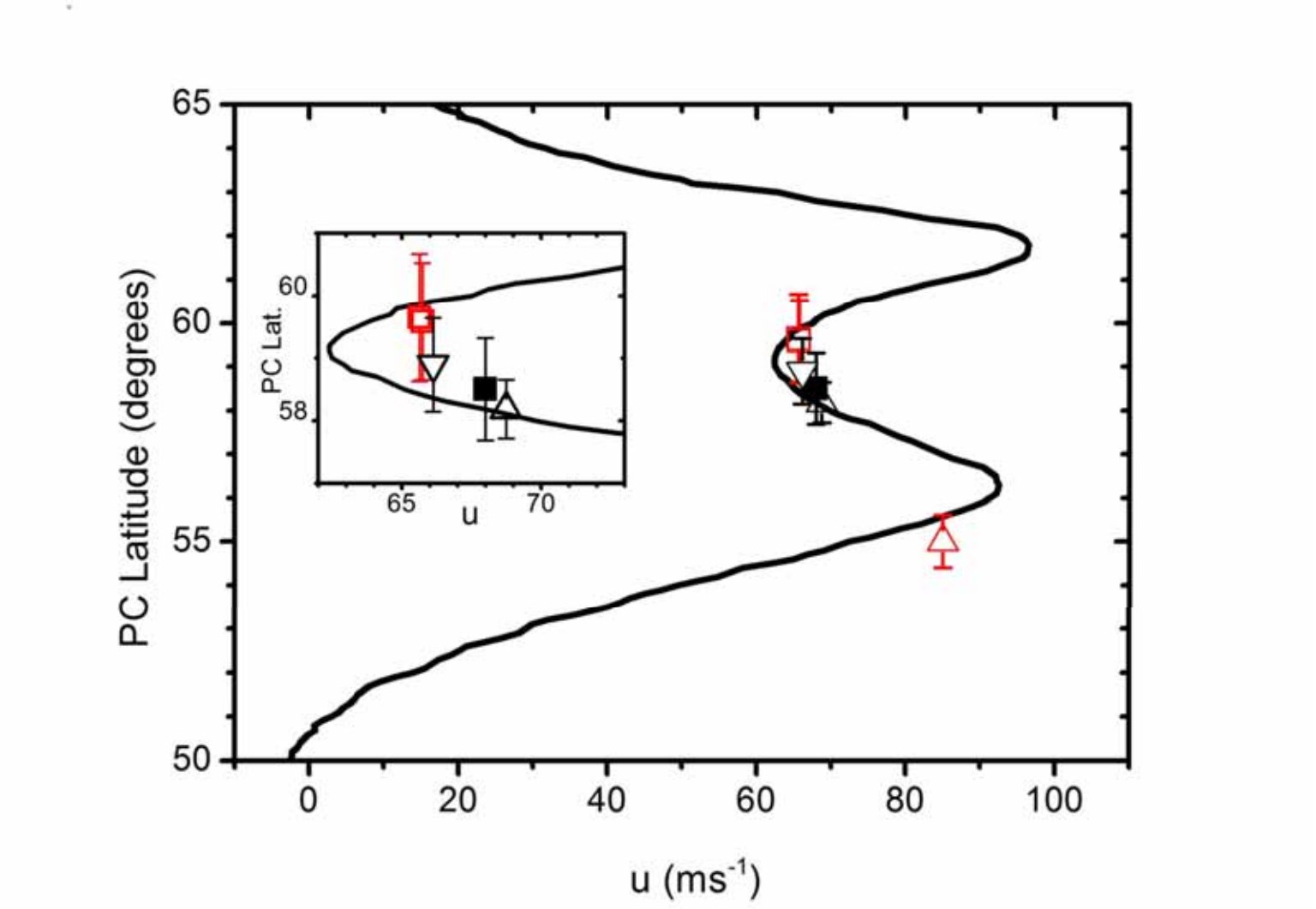
- ✓ Probably present since 2007.
- ✓ After 2012 consistently surrounded by the two anticyclones (ACA system)



To analise the motion of the system, we follow the location of the cyclone at the center of the ACA system

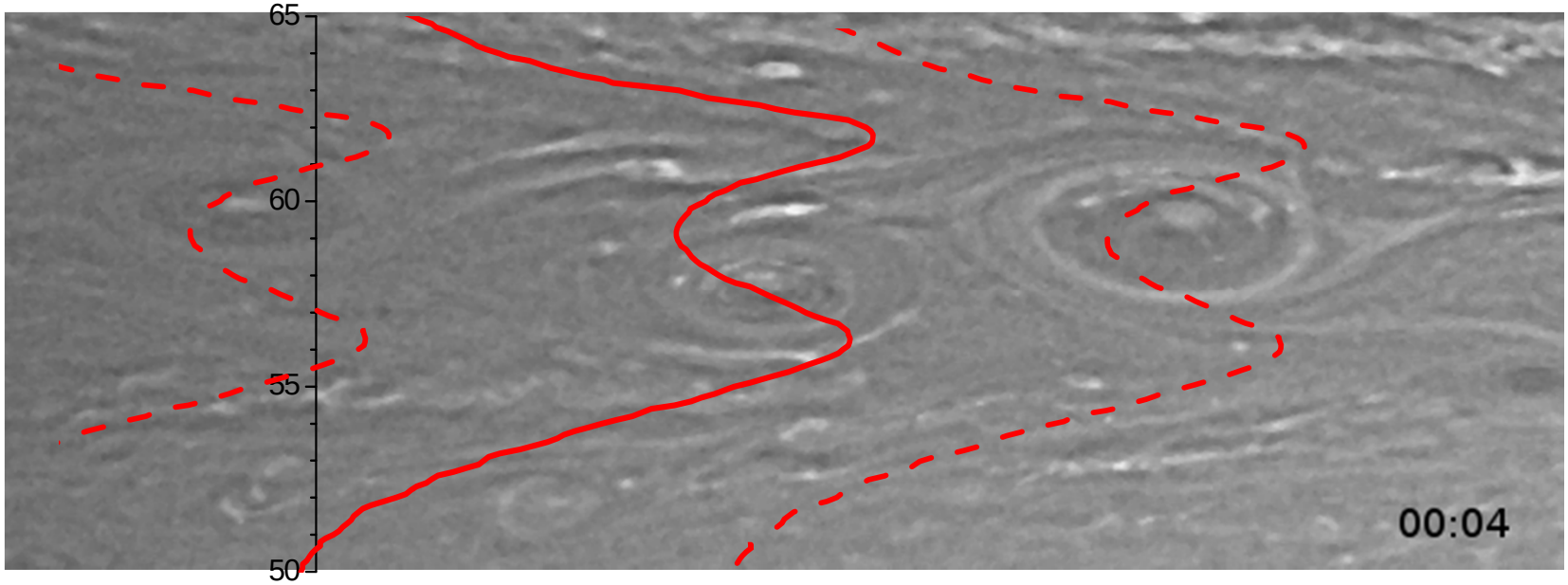


As expected, motion of vortices fits the zonal wind profile



Local motions:

- ✓ Use a couple of high resolution images separated by approximately two hours to track the motion of clouds
- ✓ Local motions are more easily analyzed in the more penetrating CB2 or CB3 filters, where the vortex is less contrasted but shows richer morphology

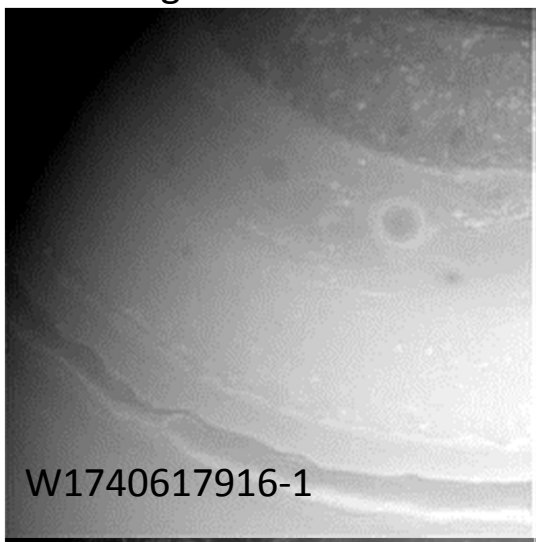


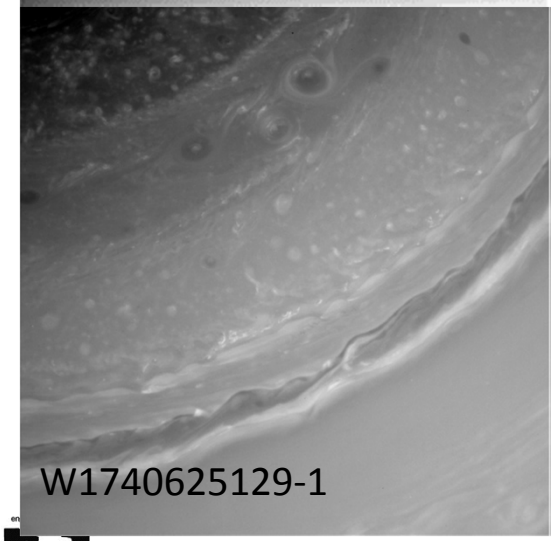
2013-Feb-27:

Cassini WAC CB2 images, projected and processed, and shifted to appreciate the local motions.

Local motions:

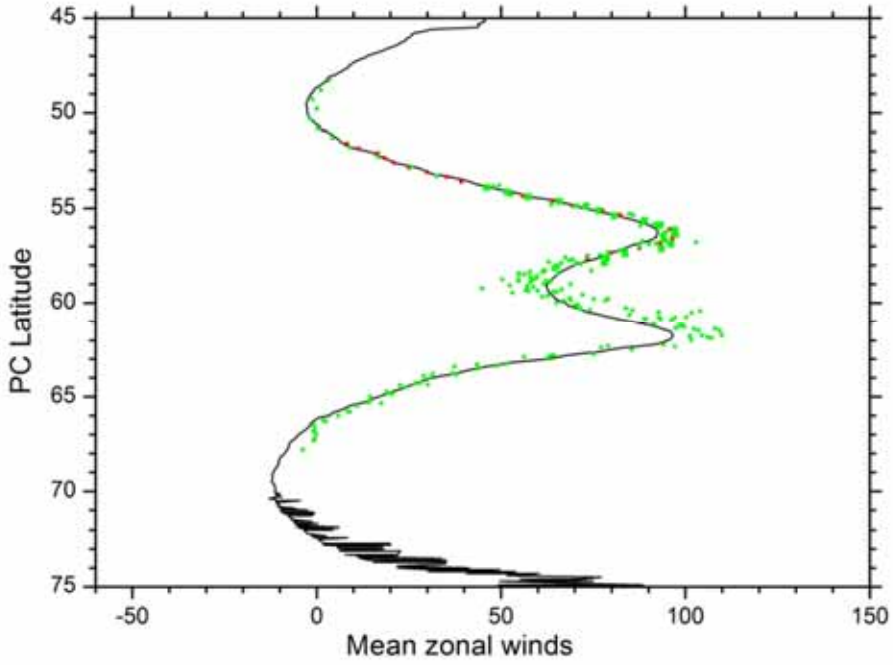
- ✓ Original images of 27th Feb 2013, separated by 2 hours. No limb in the images to aid navigation





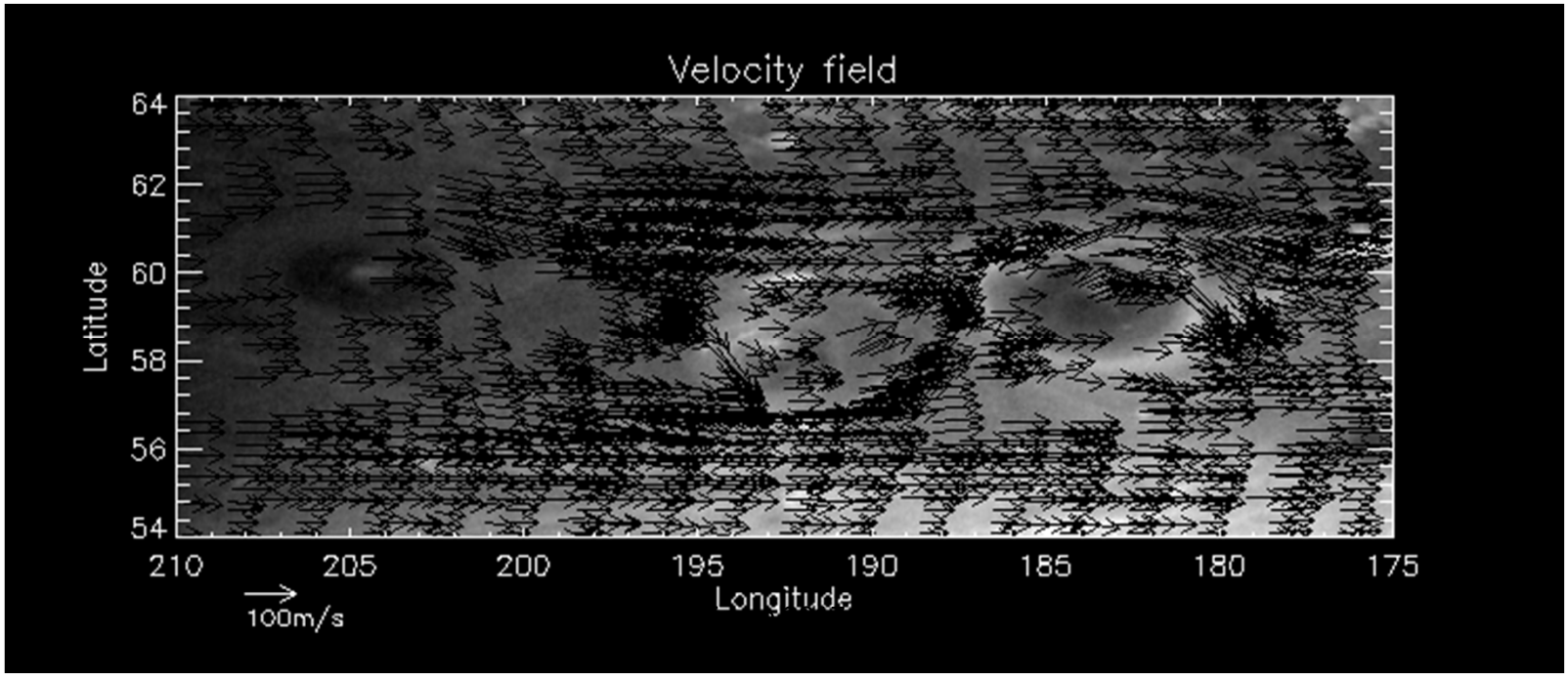
Technique developed by Ricardo:

Change navigation until zonal winds outside the tripole are properly retrieved.



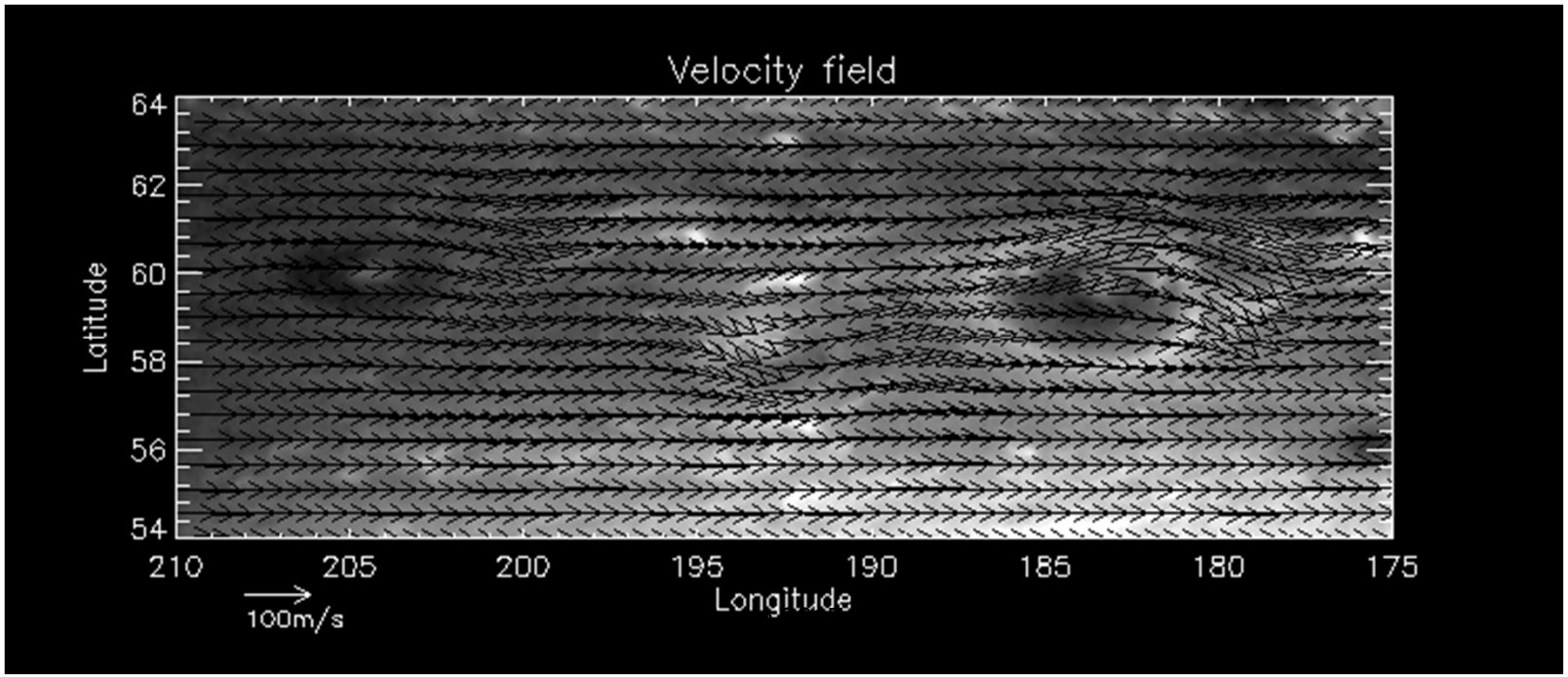
Local motions:

- ✓ PIC2V with boxes of different sizes adapted to different regions



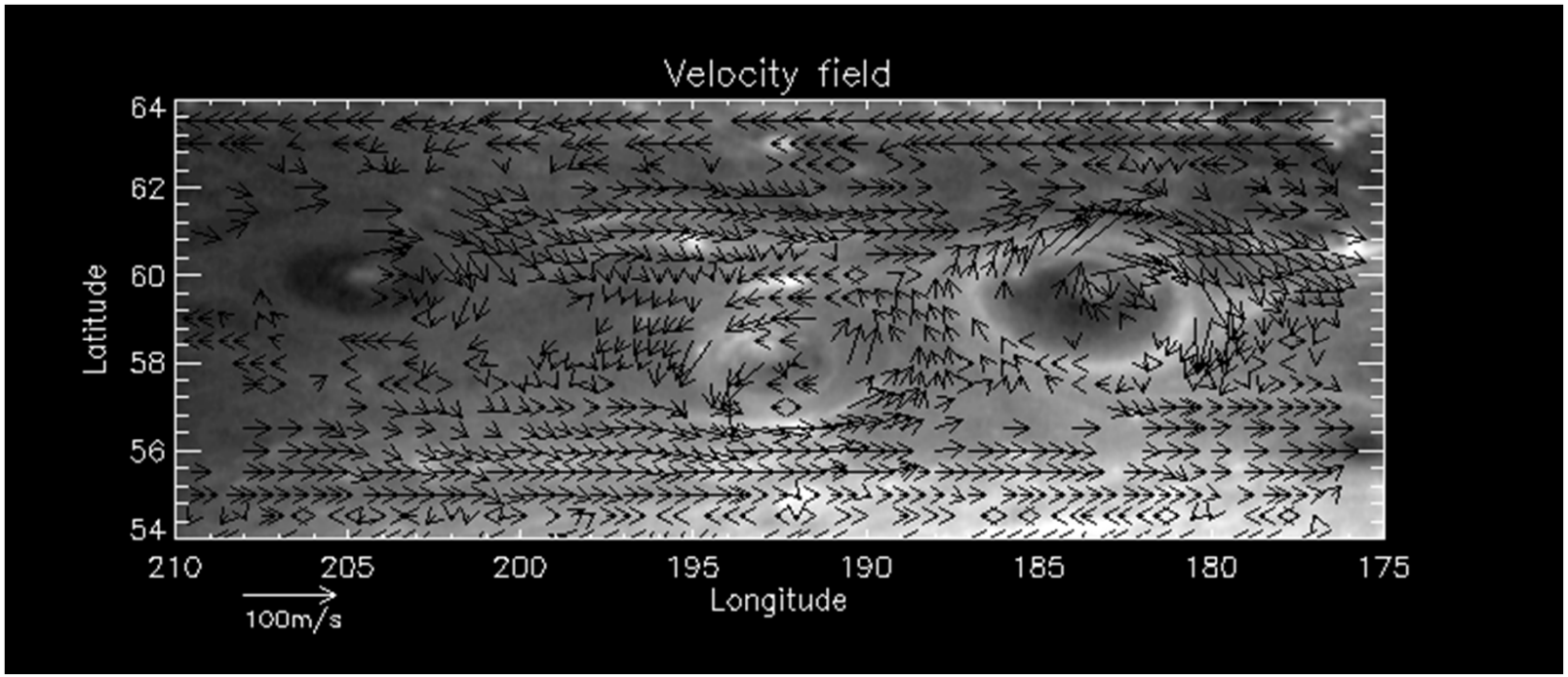
Local motions:

- ✓ PIC2V with boxes of different sizes adapted to different regions
- ✓ Results interpolated into a 0.5º grid



Local motions:

- ✓ PIC2V with boxes of different sizes adapted to different regions
- ✓ Results interpolated into a 0.5º grid
- ✓ If we look at motions in the reference system of the cyclone…



Local motions:

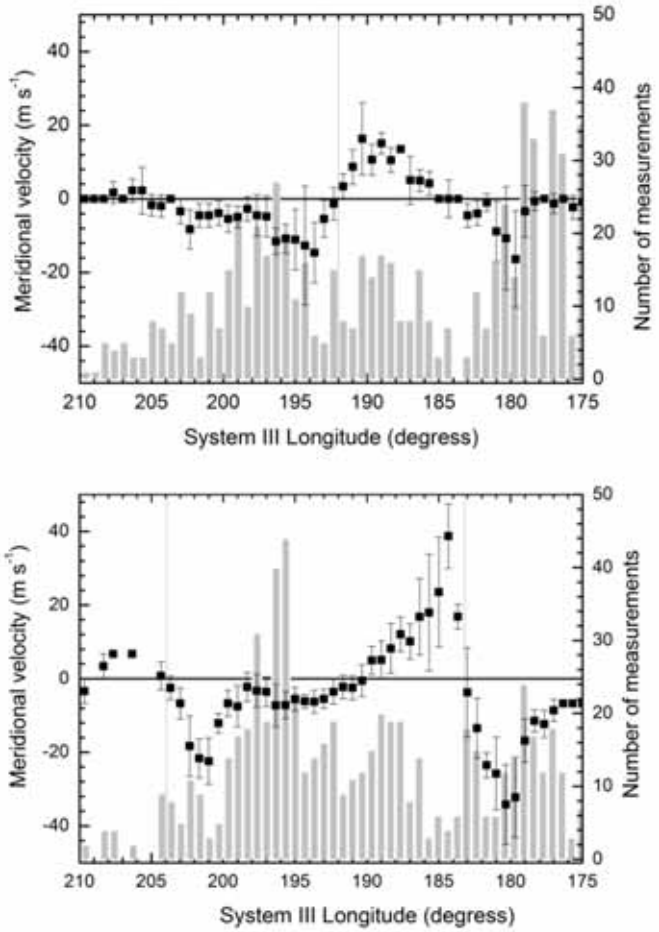
- ✓ Meridional motions are evident
- ✓ Perform averages of meridional wind in the cyclonic and anticyclonic regions of the inner double peak

Enhancement of vorticity:

- ✓ Assume constant velocity in a circle, and constant vorticity inside

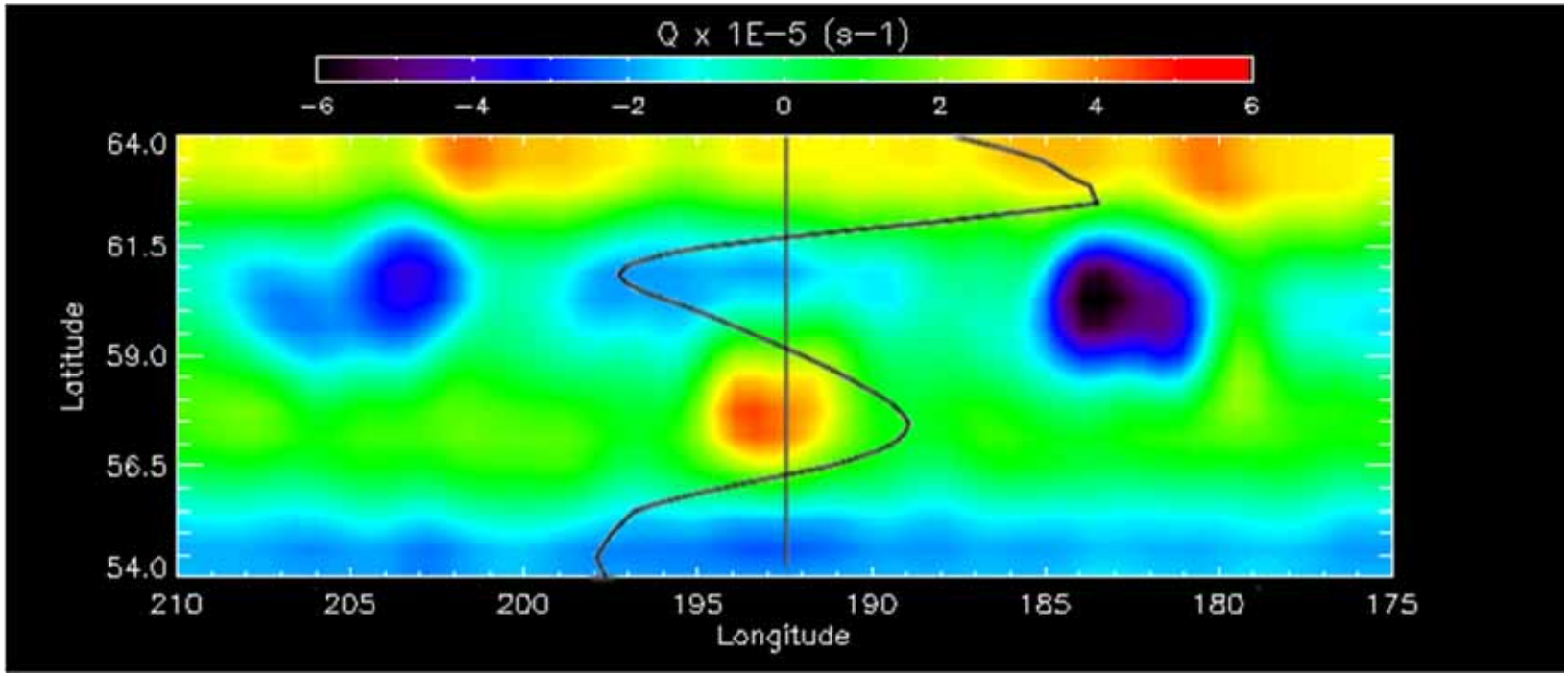
$$\left|\Delta\zeta\right| \approx \frac{2\pi r v}{\pi r^2} = \frac{2v}{r}$$

$$\boxed{\begin{aligned}\left|\Delta\zeta_{cycl}\right| &\approx (3\pm 2)\times 10^{-5}\,\mathrm{s}^{-1}\\ \left|\Delta\zeta_{ant1}\right| &\approx (5\pm 2)\times 10^{-5}\,\mathrm{s}^{-1}\\ \left|\Delta\zeta_{ant2}\right| &\approx (3\pm 2)\times 10^{-5}\,\mathrm{s}^{-1}\end{aligned}}$$



Local motions:

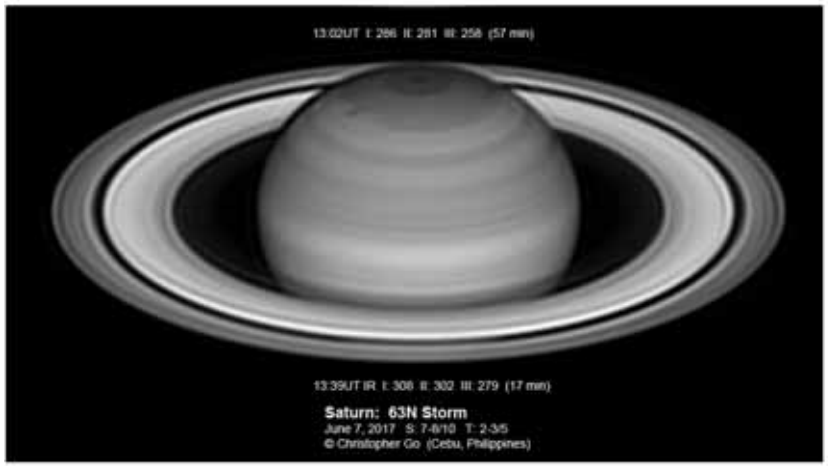
- ✓ Using finite differences in the interpolated velocity field, we can deduce ambient vorticity maps of the region



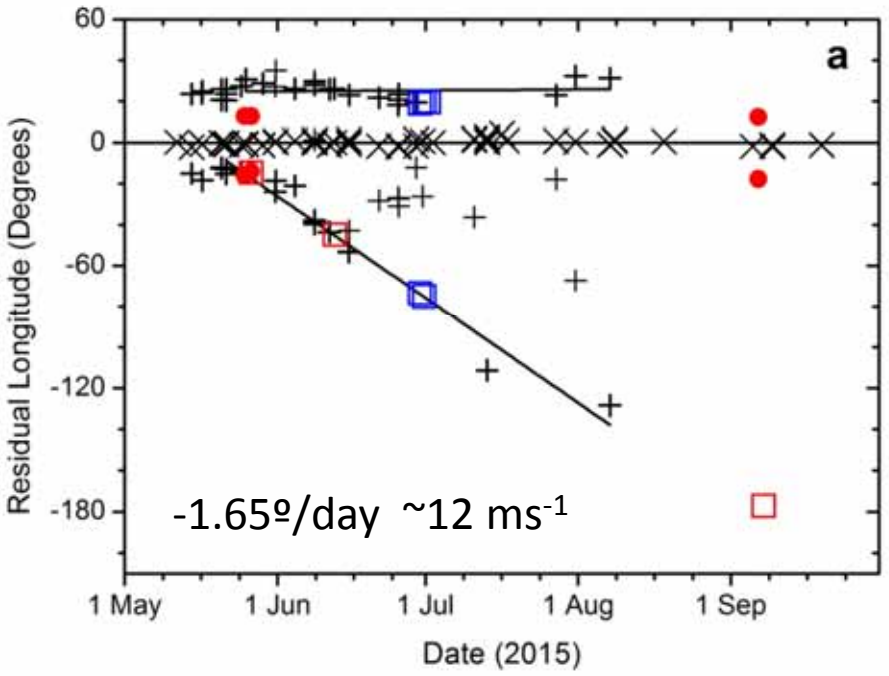
The disturbance

Zonal motion:

- ✓ To study the zonal evolution of the disturbance, we first surveyed the PVOL/IOPW database of amateur astronomer images.
- ✓ Centre and east and west limits where determined
- ✓ Graph shows evolution of the limits with respect to the position of the centre.

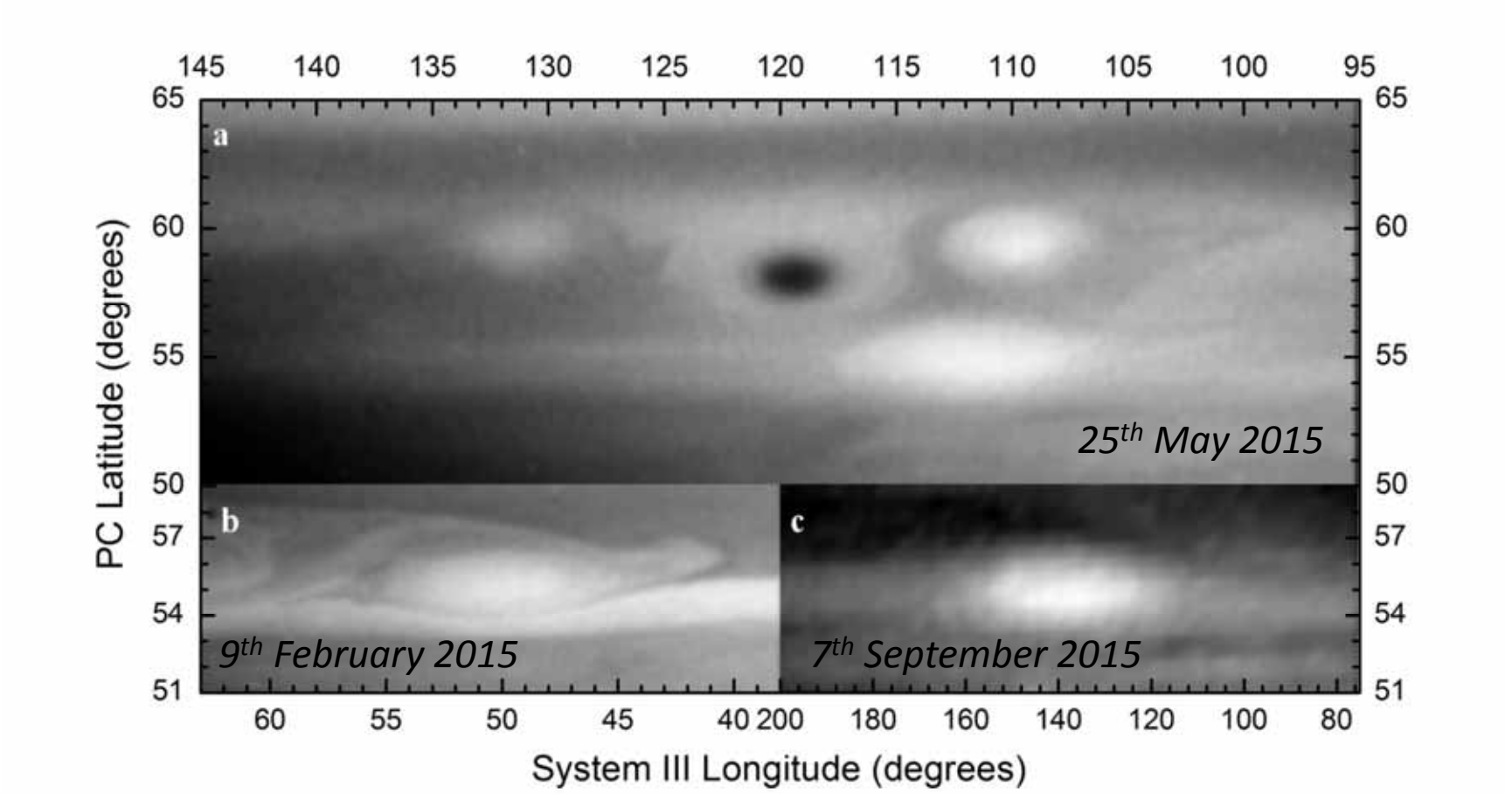


Christorpher Go, 7 June2015



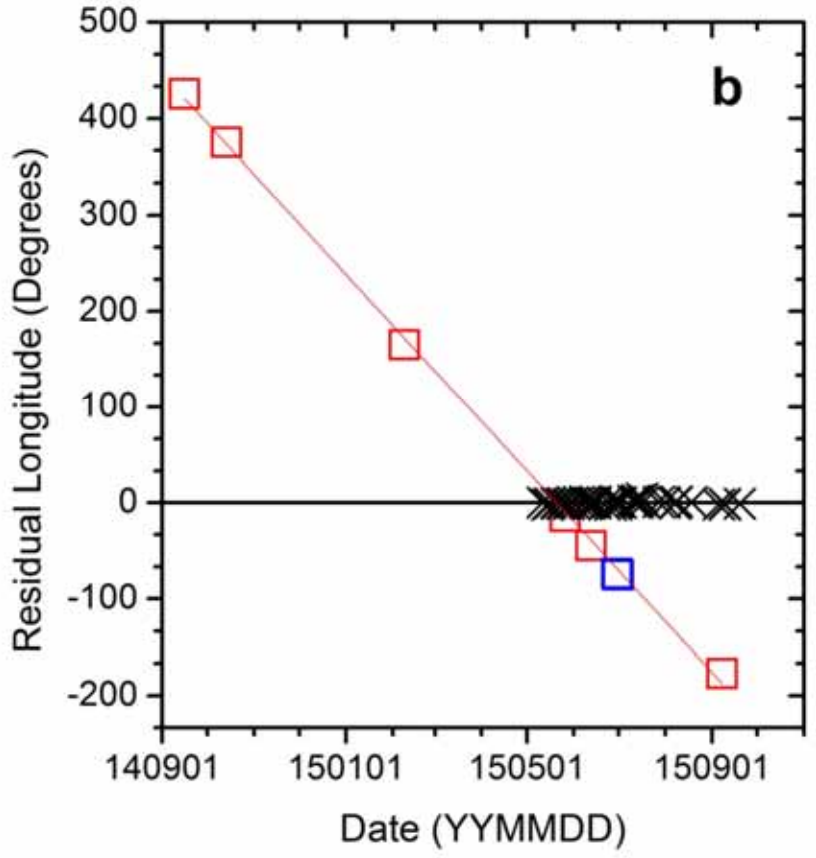
Cassini images:

- ✓ Cassini images show the presence of another vortex south of the system, at 55ºPC
- ✓ This vortex is again visible when the disturbance have subdued, in September 2015, and the expected location of the end of the disturbance (red square in previous slide)

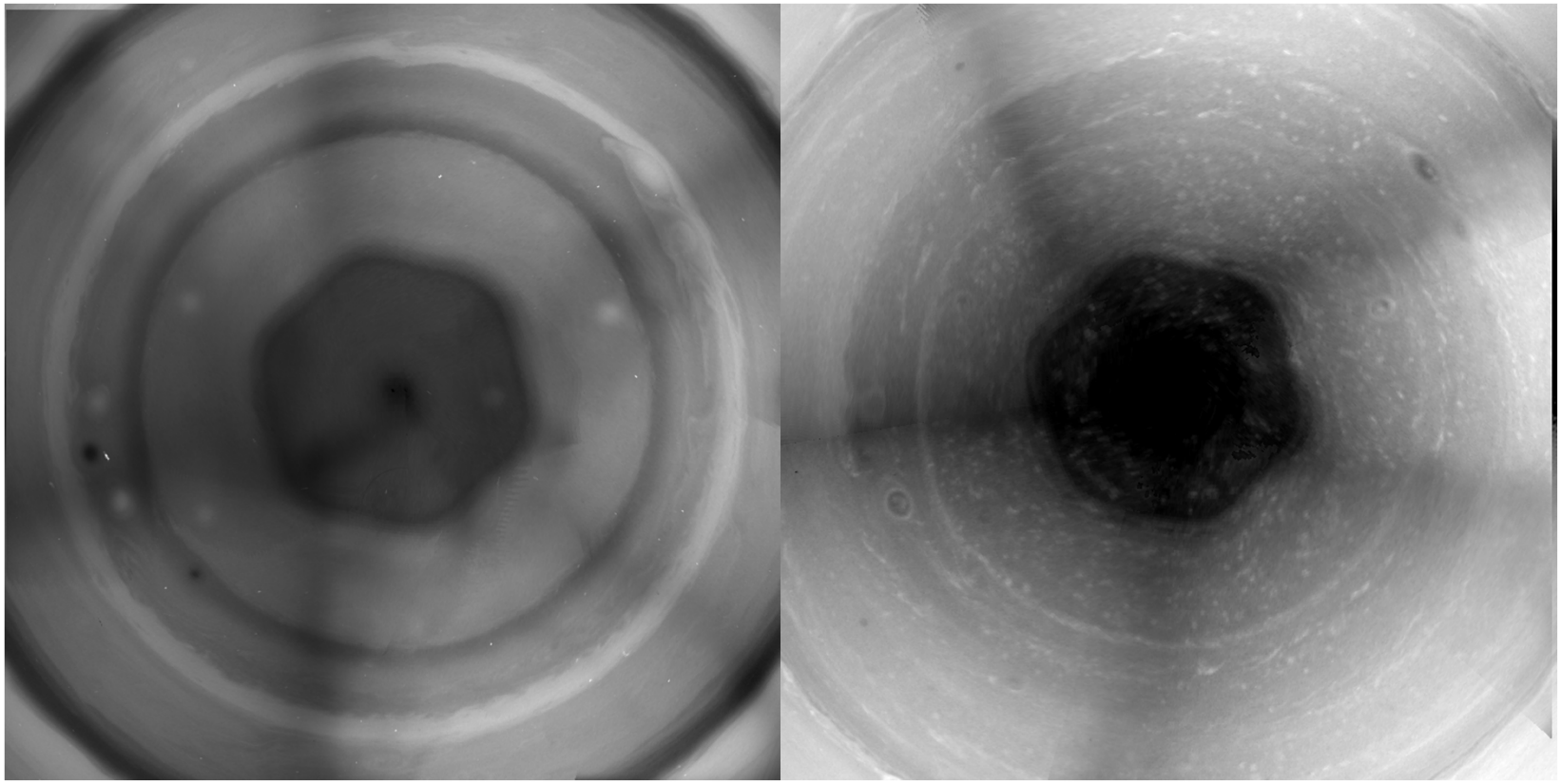


Cassini images:

- ✓ We looked for images back in time and plotted position of the vortex at 55ºPC in the reference system of the tripole
- ✓ It approaches the tripole at 1.70º/day
- ✓ We conclude that the interaction of the vortex with the tripole is a likely origin of the disturbance
- ✓ Maybe also the origin of the oscillations in zonal motion? (assuming the drift constant, crosses every 211 days)

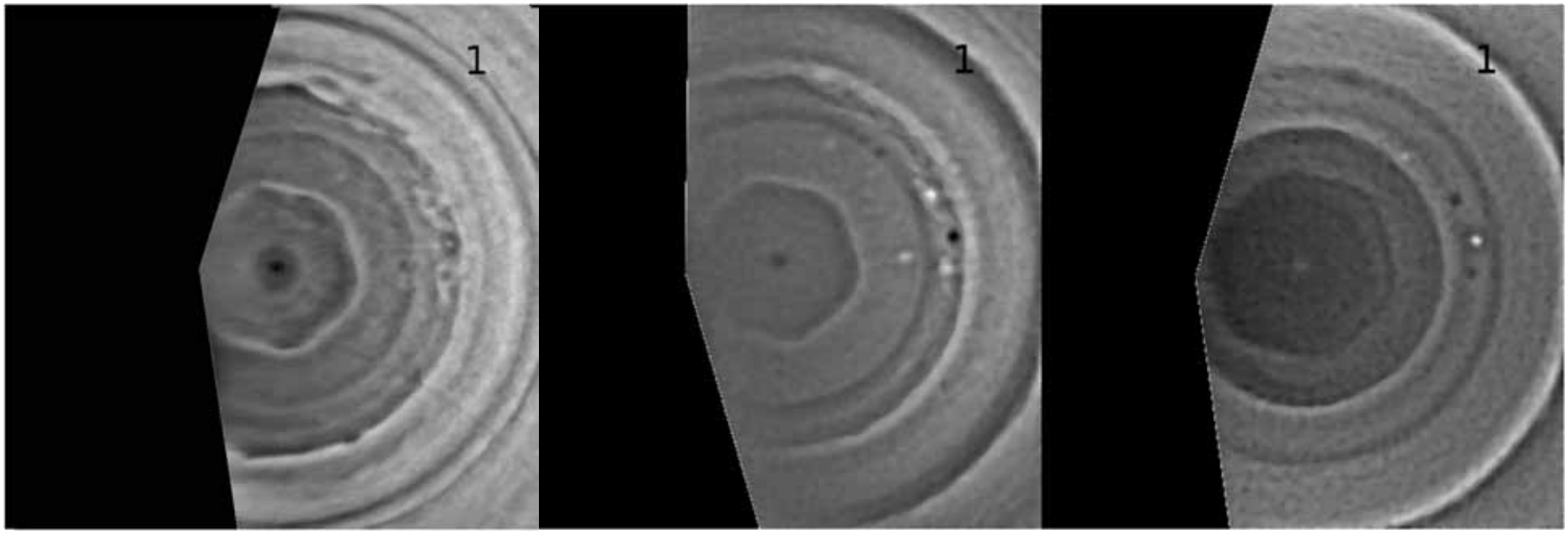


Cassini images of *9th February 2015 (105 days before the 27th of May)*



HST images of 29-30 June and 1 July

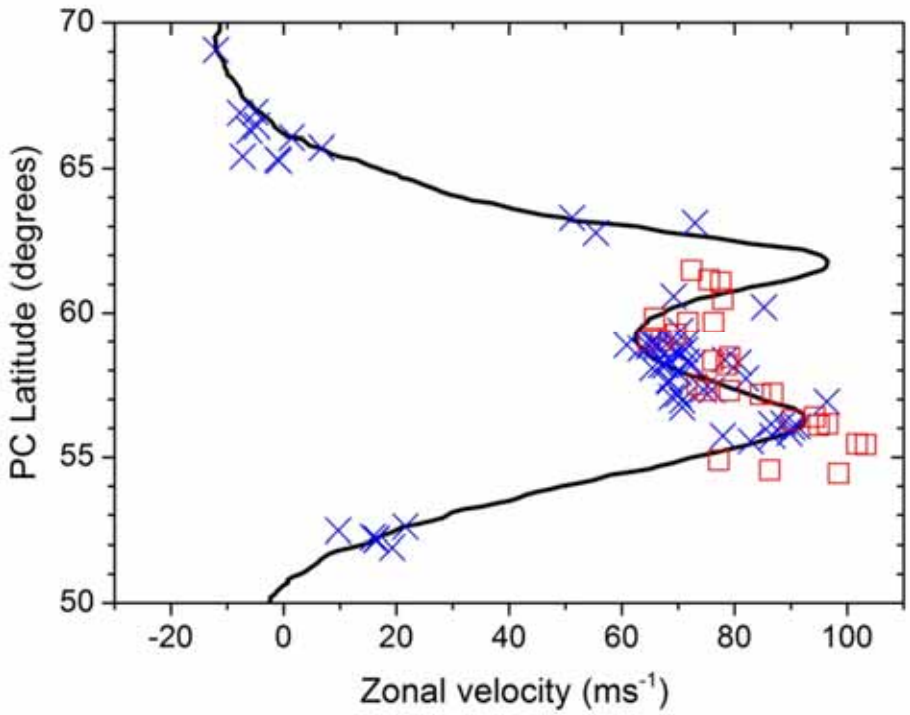
- ✓ Only high resolution images at the time of the disturbance.
- ✓ Allow us to retrieve motions of local features



Polar projections (50º-90º PG) of vortices and perturbed region the 29th June (1), 30th June (2) and 1st of July (3) in 937nm (left) 889 (middle) and 336 (right)

Zonal motions

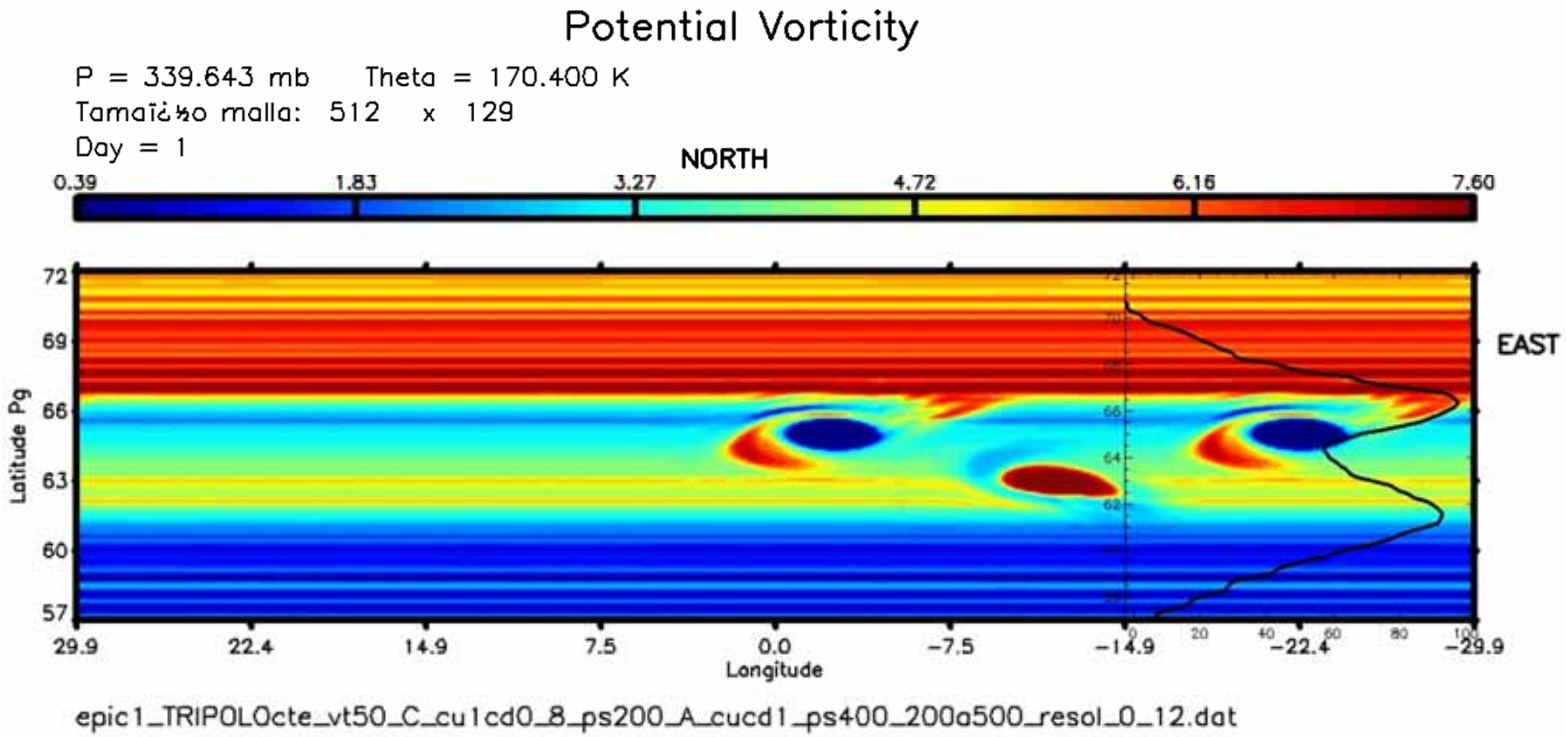
- ✓ Motion of the features essentially follows the average zonal wind profile
- ✓ Dynamics is dominated by the advection by the zonal winds
- ✓ Disturbed area is the probably the result of the advection of the clouds created by the interaction of the tripole with the vortex at the south



MODELS

EPIC (5 layers, vertical coordinate potential temperature)

- ✓ The system remains stable for a statically stable atmosphere (N~0.027×$10^{-1}s^{-1}$) with no vertical shear
- ✓ Location of vortices agrees with measured data.

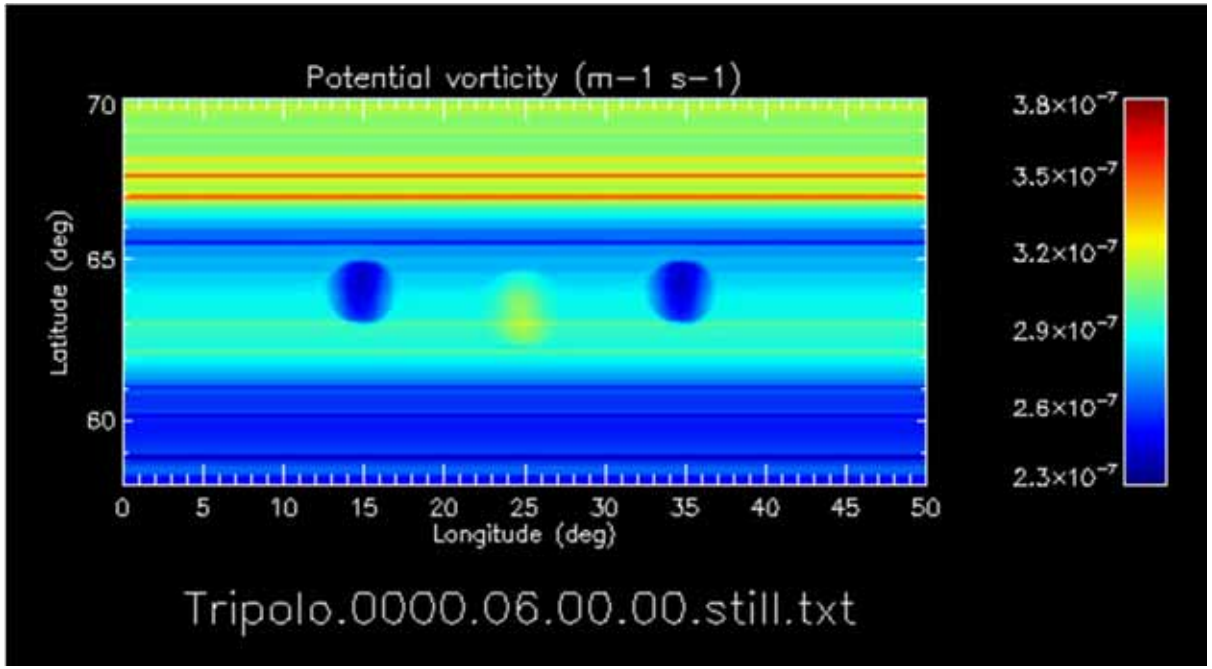


[1]*Dowling* et al. Icarus, 132, 221. 1998

MODELS

A shallow water model

- ✓ The cyclones oscillates between the anticlycones, as observed in the ACA system



[1]*Dowling* et al. Icarus, 132, 221. 1998

What we have learned

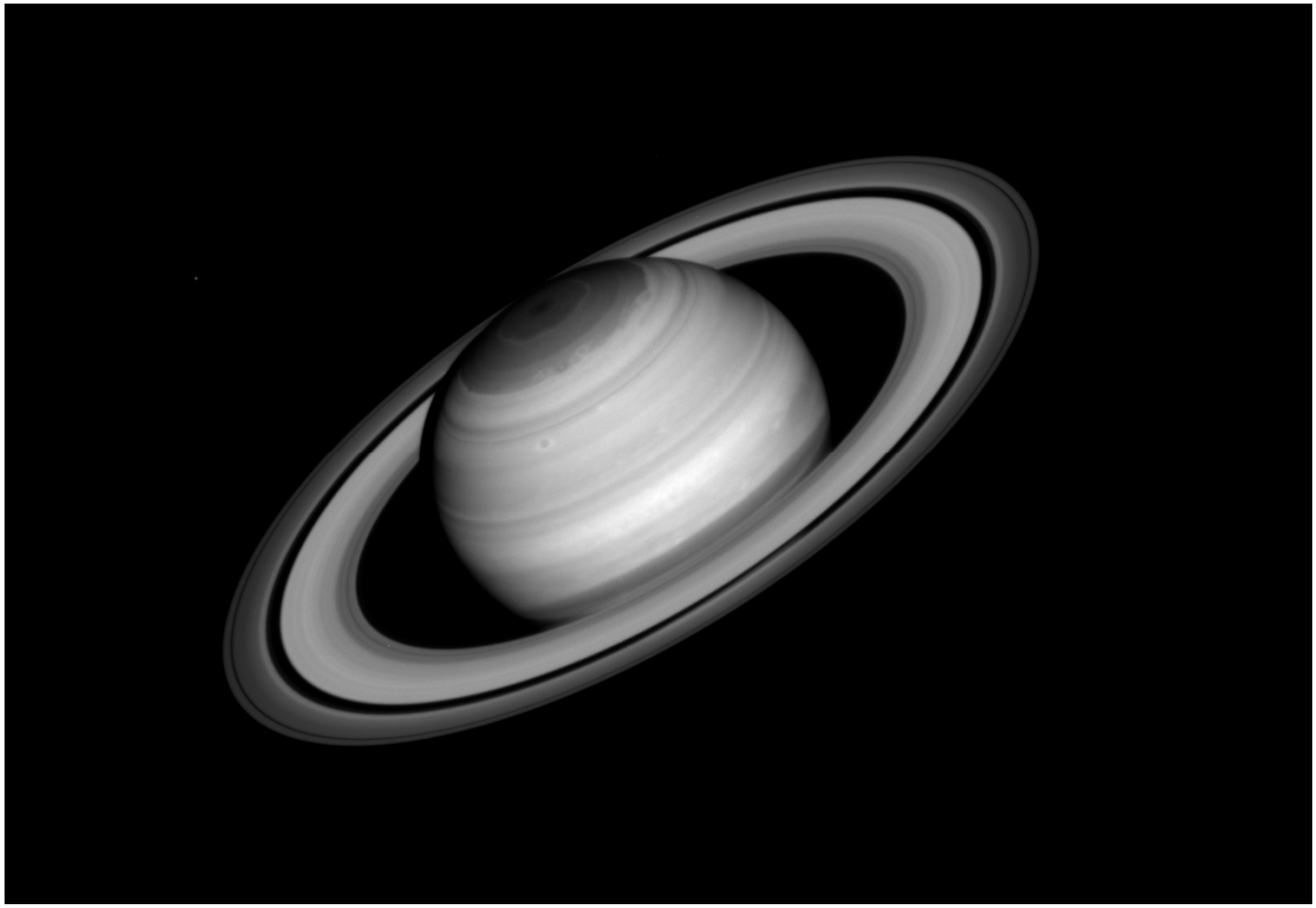
✓ A singular structure survives in the double peak since at least 2012

✓ This confirms that vortices in Saturn can be long-lived (although tricky to track)

✓We have confirmed the cyclonic / anticyclonic character of the vortices constituting the tripole

✓The disturbance was caused by the interaction of the tripole with a vortex south of it

✓Models are able to reproduce the stability and long life of the three vortex system (in the peculiar region of the double peak



Gracias por vuestra atención

The tripole system